SYNOPSIS V1.0

Microbeam Testing of SiGe Heterojunction Bipolar Transistors (HBTs) Fabricated in IBM 5HP, 6HP and 7HP

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I. INTRODUCTION

This study was undertaken to determine the charge collection response of several SiGe HBT fabricated in IBM 5HP, 6HP and 7HP process when exposed to various locations around the HBT heavy ion microbeam. The Auburn University Georgia Tech (AU/GT) collaboration provided the transistors.

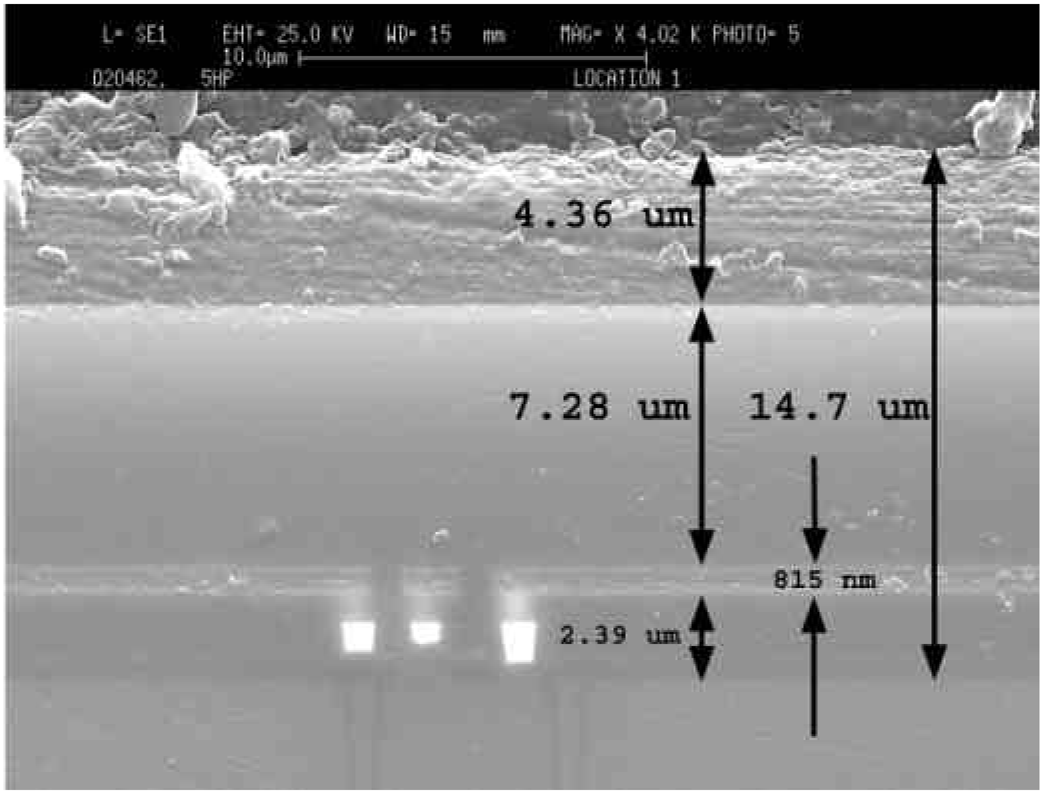
II. SPONSORS

NASA Electronic Parts and Packaging Program and the Defense Threat Reduction Agency supported AU/GT and GSFC the radiation testing. SNL Microbeam facility was supported by Defense Threat Reduction Agency supported

III. DEVICES TESTED

The sample set was eight 28 pin dip packages. Each package contained a single die. Each die had four Transistors (Tx) bonded out. There were four 5HP die, and two each 6HP and 7HP die. The Table 1, in the results section, lists each transistor by package.

Prior to microbeam testing, Tx cross-sectioning and SEM images (SEMs) were preformed at GSFC. The three images in Figure 1 show the SEMs for the 5HP, 6HP and 7HP, respectfully. An ~5 μm polyimide coating is evident in the 5HP and 6HP SEMs. While not shown in the image, the polyimide coating was also on the 7HP die. Each die was exposed to a chemical vapor etch process to remove the polyimide. This etch is required so that ions can penetrate into the Tx substrate. While most of the 24 Txs survived the etch process, 7 were damaged to the point were they could not be used for SEU testing. These are noted in Table 3 in the Test Summary section.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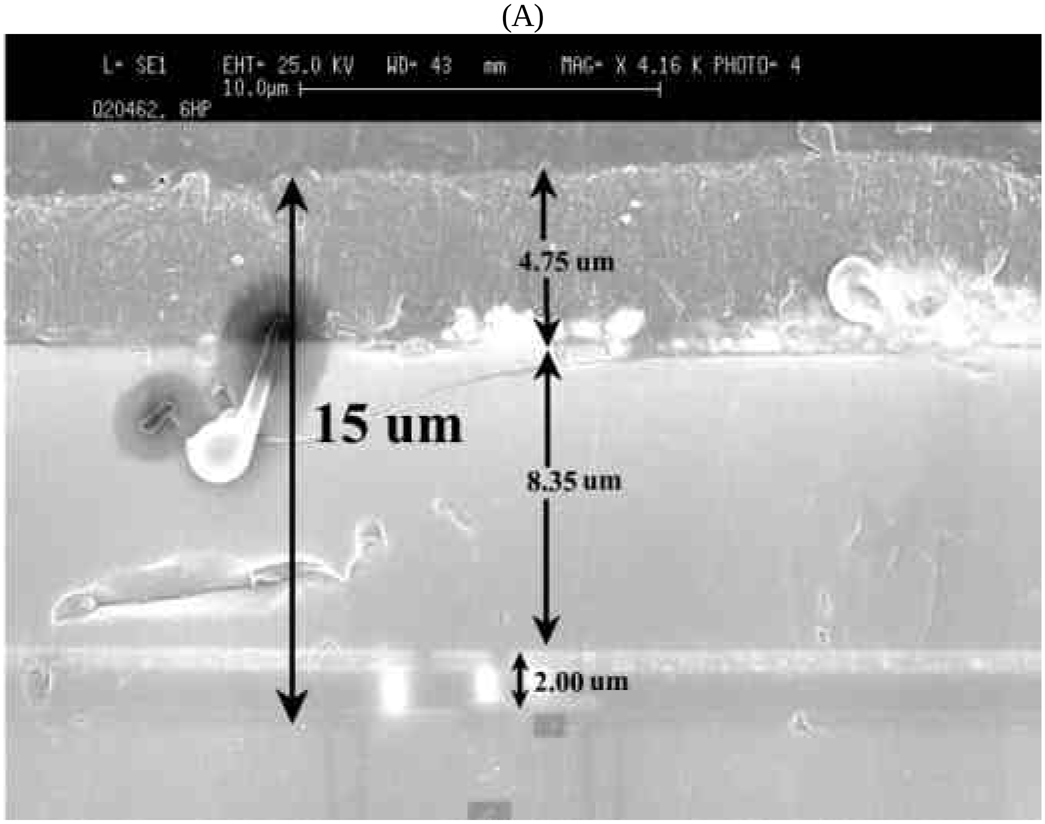
7.28 um
14.7 um
815 nm
2.39 um

(A)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020462, 6HP
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15 um
8.35 um
2.00 um

(B)

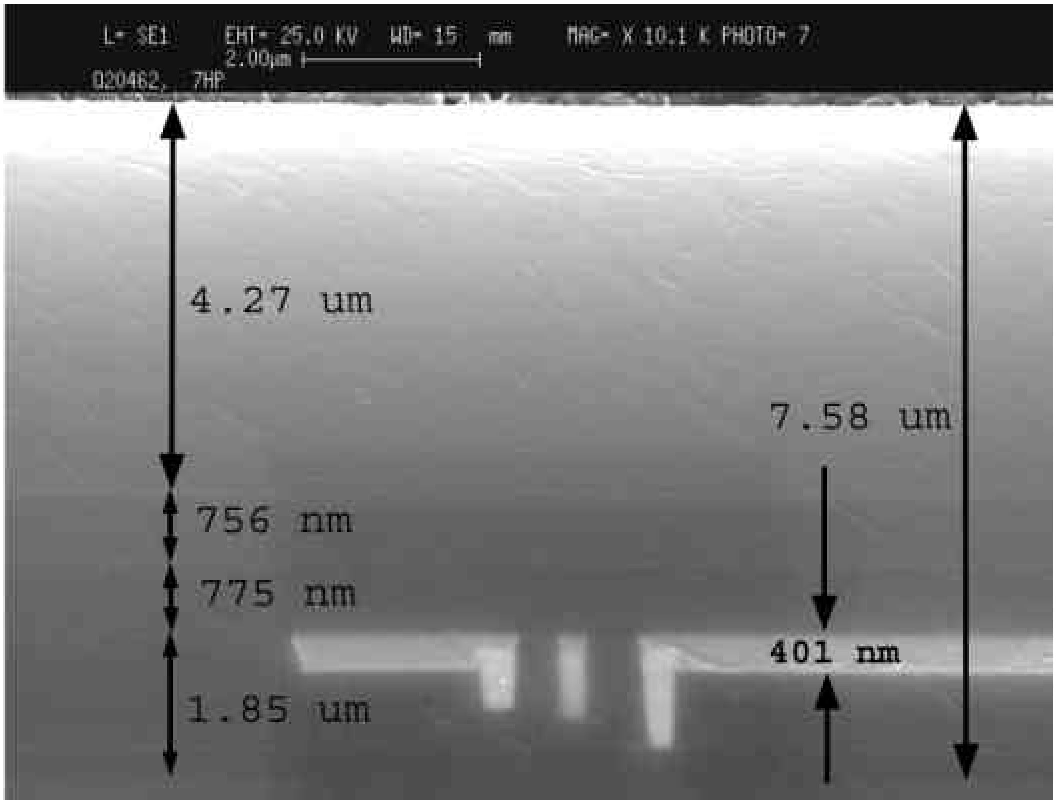

Figure 1. SEM of (A),5HP, (B) 6HP and (C) 7HP HBT transistor cross-section.

IV. TEST FACILITY AND TEST METHODS

Microbeam testing was carried out at Sandia National Laboratory's [SNL's] Microbeam Facility [1]. The ions used are given in Table 1. For all tests the ion beam spot size was near 2 μm^2. The total area exposed during one sweep (or scan) was near 1600 μm^2. The step size was near 0.1 μm. Table 2, given in the results section, give the exact spot size, scan area, and step size for each exposure.

Table 1. Heavy-ions used in this study.

Ion	Energy (MeV)
Helium-4	7
Oxygen-16	36

V. TEST METHODS

A four probe Ion Beam Induced Charge Collection (IBICC) measurement was used to simultaneously measure the charge presented on the Collector (C), Emitter (E), Base (B), and substrate (Sx) terminal due to a series of ion strikes occurring in and around the Tx area. See [2] for a complete descriptions of the IBICC technique and how it is used at SNL.

The probes were attached to each terminal of a single Tx. The beam was stepped across a large area of the die that contained the Tx of interest. A scan is one complete sweep of the microbeam across the large area (or scan window). A run is a series of scans. The data cube is the data acquired for each run. The data cube is built up by several scans of the larger area and consists of the location of the ion spot (X and Y coordinates) and the charge collected by each probe at each spot location for the entire scan.

An Agilent 4156 parametric analyzer was use to measure Gummel plots before and after most exposures (see Table 2).

Two different bias conditions were used during the test:

1) all grounded E,B,C,Sx
2) E,B,C grounded, Sx = -5.2V

A third bias condition was attempted but could not be achieved

3) B=0, C=1.0V, E at -V as a sourced current at 0.5mA/um^2 Jc, Sx = -5.2V

This condition could not be achieved because we met an unexpected problem when we tried to force an emitter current. When the forced emitter current is small (below 1uA), the sum of the IC and IB equals IE, as expected from normal operation. Such a low current, however, is too small to mimic the operation of a ECL gate. When the forced IE is increased, the emitter voltage exceeds the compliance, 20V, and the sum of IB and IC does not equal to IE. To our surprise, the transistor survived the "20V" reverse EB voltage. Considering the high risk of killing the device, we decided not to further debug the setup.

VI. TEST SUMMARY

Table 2 lists the series of exposures that were performed.

The comments section in Table 3 gives a description of the status of each Tx after the tests. The **bold** entries are the Tx's that were used during the tests. The comments section gives the ions used during the test and the condition of the Tx. The *italic* entries list the devices that could not be used for testing, the comments section lists the reason why it could not be used.

Figure 1 shows charge collection results obtained on the collector, base and substrate contacts for a 5HP 0.5mμ x 10μm transistor. Figure 2 is a 3D plot of the same including the emitter. No charge was observed on the emitter contact. Further analysis is underway for other transistors.

During test we observed that:

- Charge was conserved. The net charge flowing into and out of the Tx was zero. This was verified for run #2 on RAMUB51 Tx#4. We found that the net charge was 2.4% ±2.5% above 0.
- There was a noticeable small increase in the charge collected on the substrate contact when bias was applied to the substrate (-5.2V).
- Large charge collection events were typically due to events occurring inside the trench isolation. While small charge collection events were due to event occurring outside the trench.
- The sensitive areas scaled with Tx size.
- The sensitive area of the based appeared to decrease when bias was applied to the substrate.
- Larger LET ion caused a large amount of charge to be collected.

Table 2. Summary of devices and tests performed.

Technology	Package	Tx Number	Size	Comments
5SF	**RAMUB51**	**1**	**0.5x2.5**	**Data taken at O-16 with all grounded and at V_s = –5.2V. Tx is dead after –5.2V measurement.**
5SF	**RAMUB51**	**2**	**0.5x1.0**	**Data taken at O-16 and He with all grounded and at V_s = –5.2V Gummels after V_s = –5.2V showed Tx was not functioning.**
5SF	*RAMUB51*	*3*	*0.5x20*	*Damaged during polyimide etch*
5SF	**RAMUB51**	**4**	**0.5x10**	**Data taken with O-16 and He with all grounded and at V_s = –5.2V. Two sets of data at O-16 were taken. After the second set with V_s = –5.2V the Gummel showed that the part is dead. We note that the parametric analyzer went into a calibration mode when the cables where hooked up.**
5SF	*RAMUB52*	*1*	*0.5x2.5*	*Damaged during polyimide etch*
5SF	*RAMUB52*	*2*	*0.5x1.0*	*No substrate charge collection occurred when exposed to ions. Review of Gummel shows no subtract current. Visual verified that the bond wire going to substrate is broken.*
5SF	*RAMUB52*	*3*	*0.5x20*	*Covered by bond wire cannot test*
5SF	*RAMUB52*	*4*	*0.5x10*	*Damaged during polyimide etch*
5SF	*RAMUB53*	*1*	*0.5x2.5*	*Bond wires broken during shipping*

5SF	*RAMUB53*	*2*	*0.5x1.0*	
5SF	*RAMUB53*	*3*	*0.5x20*	
5SF	*RAMUB53*	*4*	*0.5x10*	
5SF	RAMUB54	1	0.5x2.5	Did not test
5SF	*RAMUB54*	*2*	*0.5x1.0*	*Gummel looked ok using beach tester. When inserted into chamber there was significant more collector current at low Vbe. Took at of chamber and tested on bench tester again, the noise was gone. Did not expose to ions.*
5SF	RAMUB54	3	0.5x20	Did not test
5SF	**RAMUB54**	**4**	**0.5x10**	**Data taken with He with all grounded and at V_s = –5.2V.**
6SF	**RAMUB61**	**1**	**0.32x1.04**	**Data taken with O-16 with all grounded and at V_s = –5.2V. Tx is dead after switching beam to He, did not remove part from chamber.**
6SF	**RAMUB61**	**2**	**0.32x8.4**	**Data taken with O-16 and He with all grounded and at V_s = –5.2V**
6SF	*RAMUB61*	*3*	*0.32x16.8*	*Damage during polyimide etch*
6SF	RAMUB61	4	0.32x16.8x2	Did not test
6SF	*RAMUB62*	*1*	*0.32x1.04*	*No beam was put on Tx. Post pumpdown Gummels were fine. After gummell, we hooked up amps, pins were grounded, then moved the stage. After this we noticed the Tx was noisy. Took Gummels and the parts are dead. It is possible that moving the stage is killing parts. After discovering this, we only moved stage when Tx pins were floating. We found this out on the fourth day of testing. On the fifth day no Tx were killed. This could be why other Tx died.*
6SF	*RAMUB62*	*2*	*0.32x8.4*	*Damaged during polyimide etch*
6SF	RAMUB62	3	0.32x16.8	Did not test
6SF	RAMUB62	4	0.32x16.8x2	Did not test
7SF	*RAMUB71*	*1*	*0.2x0.64*	*Tx placed in chamber and Gummel preformed after pumpdown, Tx is fine. The next morning Gummel show it to be dead. No beam was ever put on Tx.*

7SF	*RAMUB71*	*2*	*0.2x2.56*	*Damage during polyimide etch*
7SF	**RAMUB71**	**3**	**0.2x19.2**	**Data taken with O-16 and He with all grounded and at V_s = – 5.2V.**
7SF	RAMUB71	4	0.16x19.2x2	Did not test
7SF	*RAMUB72*	*1*	*0.2x0.64*	*Damage during polyimide etch*
7SF	*RAMUB72*	*2*	*0.2x2.56*	*Tx fine after pumpdown. Tx died after only 5 scans of He beam. Very little dose applied, is not radiation damage.*
7SF	RAMUB72	3	0.2x19.2	Did not test
7SF	RAMUB72	4	0.16x19.2x2	Did not test

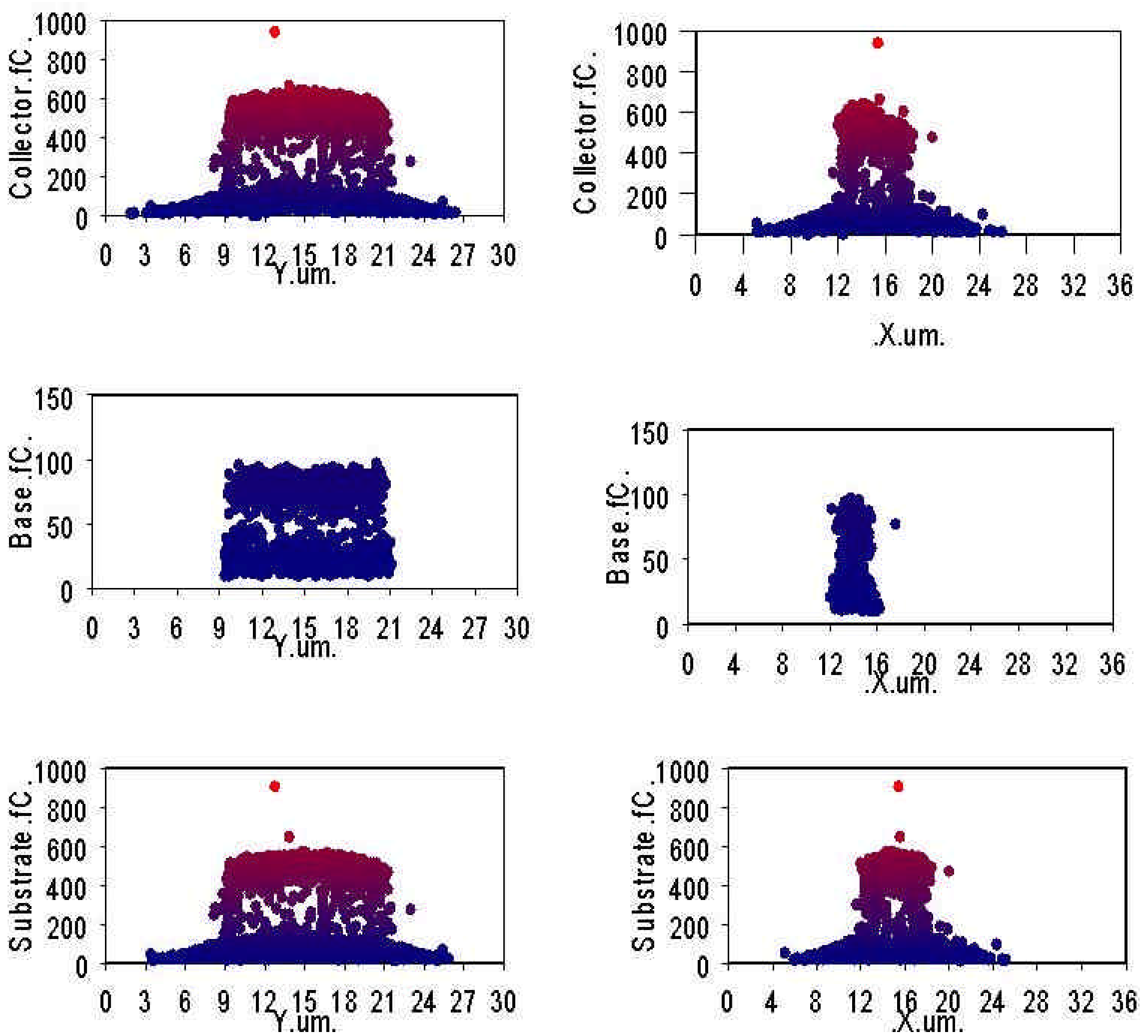

Figure 1. Charge collection results for base, collector and substrate contact for 5HP 0.5µm x 10µm transistor.

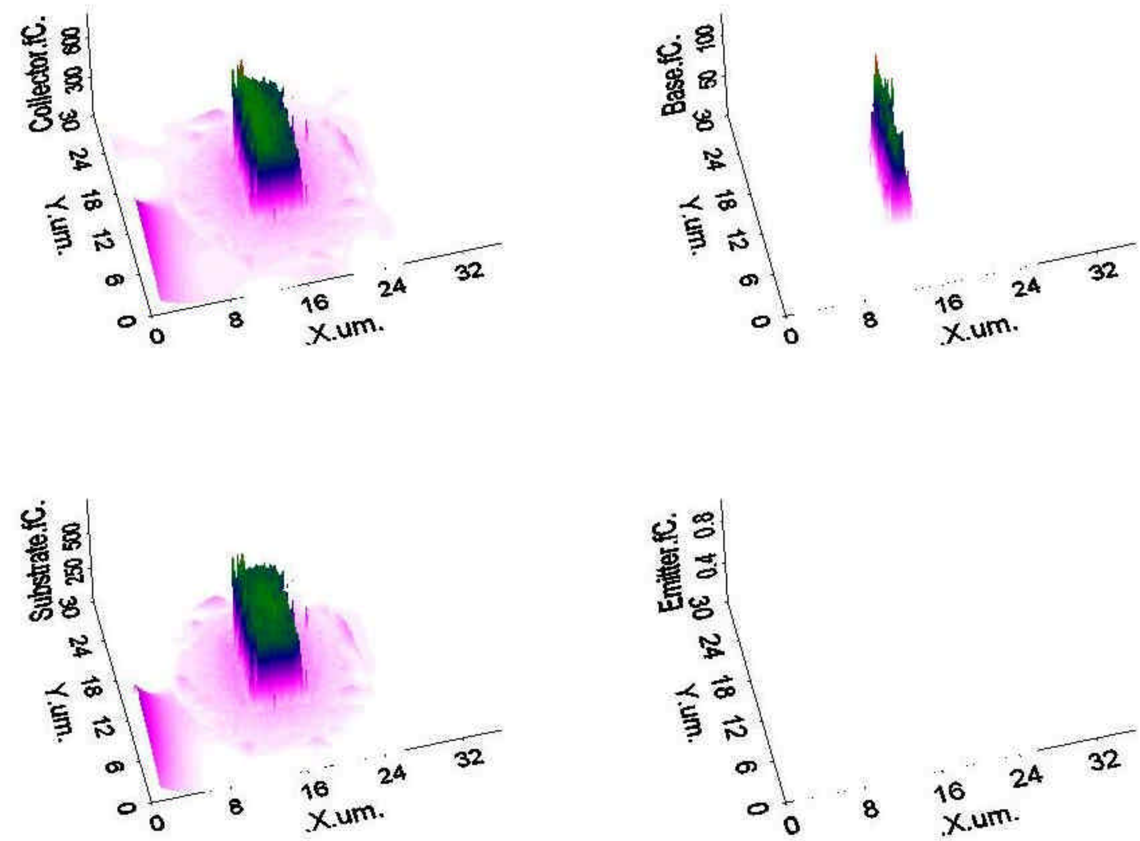

Figure 2. 3D plots of charge collection results for base, collector, substrate and emitter contact for 5HP 0.5µm x 10µm transistor.